

NREL/TRAC Educational Module

Title: Renewable Energy and Photovoltaics

Author: Mark Guengerich

Course/Grade Level: Physics/11th&12th

Objectives: When finished with this module, students should be able to:

- Compare and contrast various renewable and non-renewable sources of energy, including abundance, cost structure, and environmental impact
- Describe the function of and uses for photovoltaic devices
- Measure and graphically represent the power produced by a solar cell under varying load conditions
- Represent multiple sets of data on a single graph using graphing software
- Determine which part of the visible spectrum a given solar cell takes advantage of
- Discuss the energy available from different parts of the solar spectrum

NSES Standards:

Standard A (Science as Inquiry)

Standard B - 6 (Physical Science - Interactions of energy and matter)

Standard F – 3 (Science in personal and social perspectives – Natural resources)

Standard F – 4 (– Environmental quality)

Standard F – 5 (– Natural and human-induced hazards)

Standard F – 6 (– Science and technology in local national and global challenges)

Colorado Science Standards:

Standard 1 (Scientific Investigation)

Standard 2.2 (Energy transfer and transformation)

Standard 5 (Science, technology, and human activity)

Standard 6 (Science as a way of knowing)

NCTM Mathematics Standards:

Representation

Colorado Mathematics Standards:

Standard 3 (Data collection and analysis)

Background Skills and Knowledge Required:

- Use of digital multi-meter to measure voltage and current
- Calculations of voltage, current, resistance, and power
- Ability to build simple series and parallel circuits and read circuit diagrams
- Concept of the electromagnetic spectrum, especially visible portion
- Use of graphing software and basic internet and library research tools

Activities:

1. Sources of energy knowledge inventory (classroom small group discussion and reporting).
2. “Getting to know your PV Device” activity.
3. “What is your Solar Cell’s Favorite Color?” activity.
4. Renewable energy informational brochure (on some form other than PV).
5. Unit Assessment (“Renewable Energy Quiz”)

Notes to Teacher and Materials List:

Activity 1 – Sources of energy knowledge inventory:

Have the students in small groups come up with a list of all the sources of energy they can think of. Then have them classify them according to some classification scheme (any one they pick). After 5 –10 minutes, have them report to the class by putting their scheme on a transparency and displaying it to the class on OHP. Discuss each scheme after it is presented. After all groups have presented, give them the classification scheme renewable/non-renewable and have them reclassify their sources. Compile all of these groups results from this scheme into one pair of lists on the board or OHP.

Activity 2 – Getting to know your PV Device:

Materials: (for each lab group):

- 1 digital multimeter (or 1 voltmeter and 1 ammeter)
- 6 or more connecting wires
- 1 or more solar panels (preferably at least 1 watt)
- various resistors and/or bulbs (or any other electrical loads)
- computer with some kind of graphing software

An example procedure might be to vary the current (by changing resistors in the circuit) at a certain distance from a light source and then repeat for several different distances from the light source. The analysis graph would then be a graph with current on the x-axis and power on the y-axis. Each different distance would be represented by a different curve on the graph.

NOTE that in all cases both current and voltage have to be measured each time, and then power calculated from $P=I \cdot V$.

Grading:

I usually require a typed lab report with graphics and/or tables pasted in (not separate sheets, staples on). They need the four sections I have listed in the assignment description. Obviously data and procedure will be the same for each member of the same group, but I give a zero if the conclusion paragraph(s) are the same. Your grading can obviously be adapted to the way you normally handle labs.

Activity 3 – What is Your Solar Cell’s Favorite Color?

Materials:

- Same as Activity 2
- color filter sheets.

NOTE that you should try to get a uniform set of filters from a science supply company so as not to compare “apples to oranges”.

For procedure hopefully they will realize that they should just measure voltage and current (and calculate power) with the different colors filtered. A graph they might choose to make is a bar graph with height representing power and each bar representing a separate color.

Grading: See activity 2.

Activity 4 – Renewable Energy Brochure Assignment

Materials: Each student needs access to a computer with either a word processing or a desktop publishing program.

Activity 5 – Renewable Energy Quiz

Scoring for quiz:

1. 6 pts -one each advantage and disadvantage (Answers vary.)
2. 2 pts (Answers depend on your class’ results)
3. 4 pts – one each answer and reason (Answers vary depending on your state/country)
4. 3 pts (they should describe connection to grid, battery storage, hydrogen storage/fuel cell, or generators)
5. 3 pts solution:
 $0.30\text{kW} \cdot 12 \text{ h/day} = 0.36 \text{ kWh/day}$
 $0.36\text{kWh/day} \cdot 31 \text{ days} = 11.16 \text{ kWh}$
 $11.16 \text{ kWh} \cdot 0.75 = 8.37 \text{ kWh (one module)}$
 $206\text{kWh} \div 8.37 \text{ kWh} = 24.6 \rightarrow \mathbf{25 \text{ modules}}$

Physics

Getting to Know Your PV Device

Objectives:

- Become familiar with the function of a solar cell
- Measure and graphically represent the power produced by a solar cell under varying conditions
- Represent multiple sets of data on the same graph using graphing software

Procedure:

Design an experimental procedure to measure the power produced by a solar cell while varying two parameters. Have the teacher check your procedure before you start work.

Data and Analysis:

Your report must include a single graph representing all of your results for both parameters.

Conclusions:

Explain in paragraph form what you did and what you learned about the solar cell. Be sure to refer to your graph and to include at least two sources of error. Minimum 100 words.

What is Your Solar Cell's Favorite Color

Objectives:

- Determine which parts of the visible spectrum a given solar cell uses

Procedure:

Design an experimental procedure that uses colored filters to measure the power produced by a solar cell when different colors of light are incident on it. Have the teacher check your procedure before you start work.

Data and Analysis:

Your report must include a graphical representation of your results.

Conclusions:

Explain in paragraph form what you did and what you learned about the solar cell. Be sure to refer to your graph and to include at least two sources of error. Minimum 100 words.

Renewable Energy Brochure Assignment

Objectives:

- Become familiar with one form of renewable energy other than photovoltaics

Assignment:

Produce an informational brochure about one form of renewable energy for adult visitors to National Renewable Energy Lab (NREL).

The brochure must address the following areas:

- general explanation of how energy is used
- major and minor uses (e.g. home electricity, heating, transportation, large scale electricity generation, etc)
- types and price ranges of costs involved for at least two kinds of uses
- whether the form is intermittent, and if so, what can be done when the energy is not available
- the parts of the country and/or world in which the form of energy is most available
- current or projected near future amount of use of the form of energy
- environmental advantages **and** disadvantages

The brochure must include:

- at least one graphical representation of data
- at least one photo of a common use of the form of energy
- proper footnoting and (if applicable) copyright permissions
- at least two URL's for web sites related to the form of energy

Renewable Energy Quiz

(Answer on your own paper. **Must show work on calculation problem.**)

1. Give one advantage and one disadvantage of each of three different forms of renewable energy.
2. What parts of the visible spectrum were used most by the solar cells we had in class?
3. Identify one kind of renewable energy well suited to Colorado and one not well suited to Colorado **and explain why** in each case.
4. Describe one method of compensating for the fact that solar energy is intermittent.
5. Mr. G. used 206 kWh of electrical energy last month. Assume that some solar modules are producing 30.0 W of power for an average of 12 hours per day. What is the minimum number of such modules needed to supply Mr. G's electricity for a (31 day) month (assuming 75% efficiency)?